

DEVELOPMENT OF THE CASSINI GROUND DATA SYSTEM IN A MULTIMISSION ENVIRONMENT

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G. Madrid and G. Wanczuk

Jet Propulsion Laboratory, California Institute of Technology

ABSTRACT

As baselined, the Cassini Ground Data System (GDS) will be composed of Project-specific and multimission elements. The former will be developed by the Cassini Project and the latter by two JPL institutional organizations, the Telecommunications and Data Acquisition Office (TDA) and the Multimission Operations Systems Office (MOSO).

The GDS will be developed in three principal phases : Spacecraft Test, Launch-cruise, and Science Tour, with a significant part of the development deferred until the post-launch period. New capabilities are being introduced that are key to the achievement of more cost effective operations .

Successful development of the system will require careful planning and will involve participation of diverse disciplines. This paper introduces the Cassini Project from the Ground Data System perspective and discusses development approaches expected to produce systems which meet functional and performance requirements and which will be delivered on schedule and within budget.

Key Words : system development, system adaptations, ground data system, system integration, multimission systems, testing of multimission systems.

1. INTRODUCTION

Mission Description

The Cassini Project will launch a spacecraft on a trajectory to Saturn in 1997 for the purpose of conducting scientific investigations of the planet, its composition and magnetosphere, its satellites, and its ring system. The spacecraft will carry a payload of 12 instruments and a European Space Agency (ESA) provided Titan probe which will carry 6 instruments.

Scope of GDS

The Cassini Ground System (GS) consists of the teams, procedures, hardware, software, and facilities required to operate the Cassini Mission. The Cassini Ground Data System (GDS), which is the topic of this paper, includes the hardware and software parts of the Ground System (see fig. 1). Requirements definition for the GS is now near completion and the design phase will soon be underway. The overall GS architecture will be selected early in 1993; the GDS described in this paper represents a subset of the baseline Ground System (GS) architecture.

Development Objectives

The overall development objective is to produce a ground data system which satisfies the negotiated requirements on schedule and within budget. The development is constrained by the requirement to phase as described in section 1.4 below and must include new capabilities to facilitate reduced operations costs.

Inheritance of mature software used by existing projects together with experience gained in developing multimission software and adaptations for those projects will substantially contribute to the achievement of the development objectives. Innovative variations introduced into the Integration and Test (I&T) process are intended to result in well-tested, stable deliveries to operations.

Phased Development

Budgetary constraints require that the GDS be developed in three phases : Spacecraft Test, Launch-Cruise, and Science Tour (see figs. 1 & 2). The Spacecraft Test phase will include capabilities to process telemetry data and to generate simple sequences and commands while the spacecraft is at JPL or remotely located for launch preparation . The Launch-Cruise phase will include additional capabilities to track the spacecraft, acquire data, radiate commands, and monitor the spacecraft's health. The Science Tour phase

will include additional capabilities to process and archive science data, to generate and validate complex sequences, and to perform spacecraft analysis functions with the aid of more automated software tools. All phases will include remotely-located Science Operations Planning Computers (SOPC's) which will provide processing and central data base access capabilities to the investigators.

2. GDS IMPLEMENTATION

The GDS will be composed of multimission components provided by the Multimission Operations Systems Office (MOSO), project-specific components provided by the Cassini Project Mission Operations System (MOS), and other multimission components provided by the Office of Telecommunications and Data Acquisition (TDA). This paper will focus on the MOSO and Project-provided capabilities because the main characteristics of the GDS architecture are associated with these organizations; the TDA capabilities are contained within the TDA's separate, stable, standardized architecture which has proven to be relatively independent of project variations.

TDA

The TDA-provided capabilities are delineated in Figure 1 and include the following :

Telemetry

- acquire telemetry signal
- extract data/bit synchronize

Command

- receive command information
- radiate command signal

Radio Metric

- acquire doppler data signal
- digitize signal

MOSO

The MOSO-provided capabilities are also delineated in Figure 1 and include the following :

Telemetry

- frame synchronize
- decommutate, channelize

Command

- translate to binary

Simulation

- spacecraft telemetry
- command interface

Sequence

- generate, validate, translate

Image Processing

- real time process
- systematic process analysis

Multimission Spacecraft Analysis

- monitor health and safety
- analyze trends
- assess performance
- produce predicts
- analyze anomalies

Mission Analysis and Design Tools

Science Planning Tools

MOSO development of multimission "core" capabilities is planned and carried out generally on annual cycles. Specific delivery dates are negotiated with affected projects. Capabilities proposed for inclusion in a software version are reviewed with MOSO entities and affected projects; final decision is made by MOSO.

Actual development is performed to MOSO requirements by personnel in JPL technical divisions. Reviews will be conducted consistent with MOSO standards.

Documentation of core developments is the responsibility of MOSO and is performed to MOSO standards.

Adaptation of MOSO core software is usually the responsibility of the affected project. One exception is the first time development of a MOSO core capability, in which case MOSO may also develop the adaptation.

Project-Specific

Project-specific capabilities fall into two categories: adaptation of MOSO core software and project-developed software which is independent of the MOSO-provided software. This latter category is sometimes termed "stand-alone" software.

Adaptation of MOSO core capabilities is required due to lack of standardization of spacecraft information systems design and the requirement to tailor operational interfaces to accommodate project needs. Adaptation will be applied to MOSO telemetry, command, sequence, image processing, spacecraft analysis, and navigation subsystems, as well as to science

planning tools.

The required adaptation is performed by personnel in JPL technical divisions, often by the same personnel who developed the core capabilities. Reviews will be conducted consistent with project standards.

Documentation of adaptation capabilities is the responsibility of the project and is performed to project standards.

Project-specific stand-alone software will be diverse and will include models and analysis software. This software will be developed to project requirements by project personnel or by personnel in JPL technical divisions. Reviews will be conducted consistent with the project software management plan.

Documentation will be produced consistent with the project software management plan.

3. NEW FEATURES

The Ground Data System will include several required features that are needed by the Cassini project and MOSO partly to facilitate reduced operations costs. Among the most important of these features are: the Test Telemetry and Command Subsystem (TTACS), the Multimission Spacecraft Analysis Subsystem (MSAS), and the High-Speed Spacecraft Simulator (HS-SIM).

TTACS

The Test Telemetry and Command Subsystem (TTACS) feature is a cost-saving, risk-reducing item which will support the spacecraft Assembly, Test, and Launch Operations (ATLO) phase. It is not new technology but a repackaging of the basic downlink and uplink capabilities of the multimission system, adapted for Cassini, into a portable set of two or three workstations. The TTACS can be used to support spacecraft assembly and test operations at remote JPL locations, and can later be moved to Kennedy Space Center to support the test and launch operations at that site. This capability will greatly improve the effectiveness of the Spacecraft Integration and Test Team by permitting them to control their own test string while maintaining datalinks to the main flight string at JPL. In the past, the team had either to do their testing on support equipment, completely separated from the flight control

environment, or to contend with developers and other testers for time on the flight test string. Development will also benefit because the TTACS provides early experience with the Cassini-adapted multimission system and accordingly permits an early shakedown of capabilities. Operations will benefit because the user interface will not substantially change from phase to phase, thus reducing training time and operational errors.

MSAS

The Multimission Spacecraft Analysis Subsystem (MSAS) is an entirely new development which integrates all of the spacecraft subsystem engineering analysis (including spacecraft health and safety) functions into one system with a shared data base. It provides for sharing of data and correlation of events between spacecraft subsystem analysts. Besides providing an integrated, distributed, computing environment for these functions, MSAS will also provide a set of tools which will automate many analysis tasks, thus diminishing the time and effort required to analyze and react to problems on-board the spacecraft.

MSAS will be developed using the Rapid Development Methodology which will consist of multiple deliveries each building on earlier deliveries.

MSAS is intended to reduce the size of the spacecraft teams during operations and to reduce development costs for subsequent projects. Because it replaces necessary flight control capabilities previously developed by projects, it is critical to the Cassini Mission.

HS-SIM

The software-based High Speed Spacecraft Simulator (HS-SIM) is required to satisfy the Sequence and Spacecraft Teams' requirements for a fast turn-around simulator to validate command sequences before they are radiated to the spacecraft and to support spacecraft analysis activities. Through the utilization of relatively inexpensive microchip technology, the multimission High-Speed Simulator will provide performance rates considerably in excess of real-time.

The HS-SIM will reduce operations costs and reduce risk in both the uplink and the analysis areas. In the past, simulators were

tailor-made for each mission, as required. The development of a multimission simulator will be advantageous not only to Cassini but to future missions as well, and will thus reduce overall development costs to NASA.

4. INHERITANCE AND EXPERIENCE

The initial operational version of the MOSO multimission system supported the Magellan Mission and a subsequent version is now supporting the Mars Observer Mission. Additionally, the Voyager, Ulysses, and Galileo projects are in the process of adapting the multimission system to support their respective missions, enabling the decommissioning of obsolescent data systems with substantial operations and maintenance cost reductions.

Because of this previous multimission GDS development experience, the Cassini project is obtaining a multimission system with substantial inheritance. Characteristic of all development efforts, there have been fewer problems with each succeeding version; the resolution of problems in the earlier versions adds to the stability of the succeeding versions. The version on which the Cassini GDS will be built will be derived directly from the version now in use by Mars Observer.

MOSO's multimission GDS development experience shows that the following major factors are detrimental to multimission product quality: (1) late requirements, (2) late definition of data interfaces, (3) late dependencies, (4) underestimation of required development and test resources, and (5) insufficient time for integration and test due to schedule compression resulting from the previous four problems.

In order to minimize problems in the Cassini GDS development, the following steps are being taken by the Cassini Project and MOSO: (1) timely specification of requirements and negotiation of commitments, (2) early definition of interfaces and establishment of system engineering working groups at all levels, (3) identification, tracking and follow-through on all commitments and dependencies through a receivable/deliverable reconciliation process, (4) frequent and thorough planning and review of all ground system schedules and resource plans, (5)

development of contingency plans for major delay scenarios, (6) establishment of a Project-MOSO management coordinating committee.

5. INTEGRATION AND TEST

One of the key processes involved in creating any successful ground data system is Integration and Test (I&T). When a multimission system is the subject of the I&T process an additional challenge is introduced because the multimission system elements must be adapted to meet project-specific requirements. An appropriate strategy must be selected to ensure that the combined adaptations and multimission system elements are properly integrated and tested. The following describes how this challenge is being dealt with in the development of the Cassini GDS.

Currently, the responsibility for the I&T process is divided between MOSO and the project test teams. MOSO is re-evaluating this current practice in light of the experience gained in integrating adaptations with multimission system elements. One proposal will be the formation of an integrated MOSO-Project test team to perform all of the System - level integration and test functions. The proposed test team would perform the relevant parts of the project activities known as User Acceptance Test and GDS Test. In this way the resources for testing will best be optimized to reduce overall cost.

The integration and test process for adapted multimission software is evolving as the multimission concept evolves. There are corresponding variations in the subsystem phase of adapting and integrating multimission system elements for the Cassini GDS; these occur because of the variations in the phasing of the adaptation with the core implementation. Figure 3 illustrates the three situations that occur most frequently in the I&T process. Upon analysis, we find that the three situations depicted in figure 3 are variants that occur due to the interleaving of the multimission and the project integration and test life-cycles.

The Cassini GDS will be implemented through a series of phased deliveries. The MOSO deliveries will be phased to negotiated need dates for specific capabilities. These phased deliveries must be integrated with

commitments to other projects that are also users of the multimission system elements. Scheduling of the Integration and Test of the GDS capabilities will be accomplished through a Project/MOSO coordination process.

6. CONCLUSIONS

The planned approach to development of the Cassini GDS is expected to enhance the probability of successful delivery of all required capabilities on schedule and within budget.

Requirements and interfaces are being defined early in the development lifecycle, consistent with development standards.

The multimission and project adaptation development expertise and the multimission software maturity achieved in the Magellan and Mars Observer developments will be of significant benefit to the Cassini development effort.

The Telemetry, Command, Sequence, Navigation, and Simulation subsystems will include significant inheritance from previous projects.

The Telemetry, Command, Sequence, and MSAS Subsystems will be developed such that there will be a series of deliveries with increasing capabilities; each delivery will build on the maturity of the earlier delivery.

Improvements in the test and integration processes, together with timely deliveries from development organizations, are expected to result in timely deliveries of well-tested capabilities to operations.

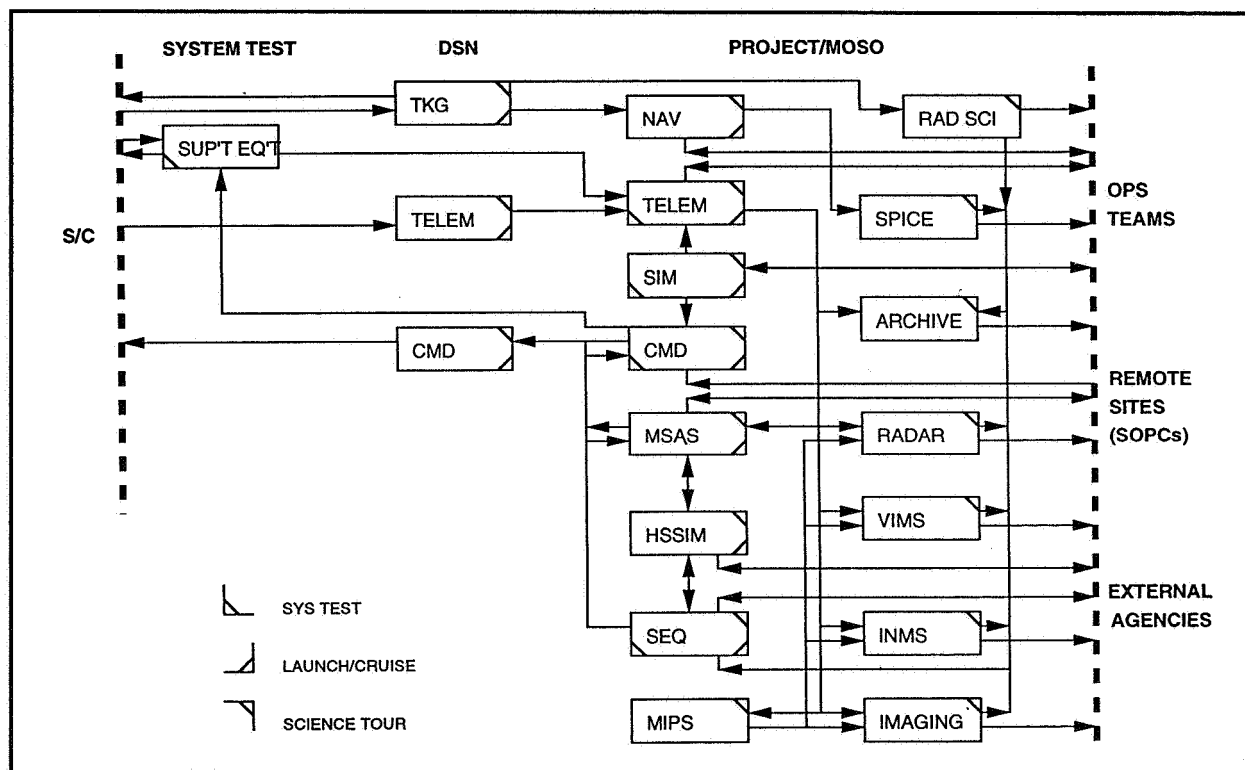


Figure 1. Diagram of the Cassini /TDA /MOSO Ground Data System

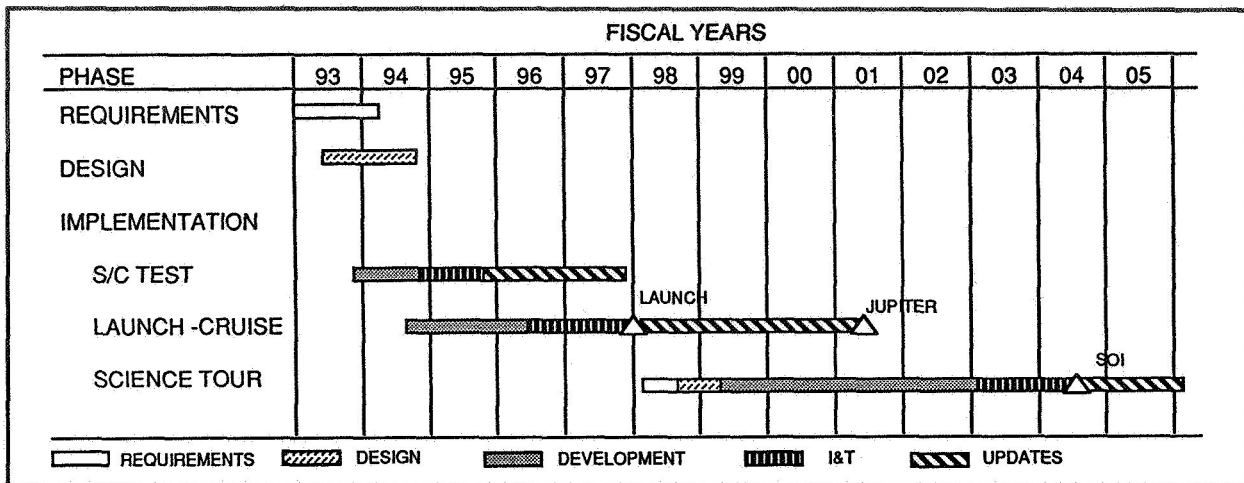


Figure 2. Phases and Principal Deliveries of the Cassini / MOSO Ground Data System

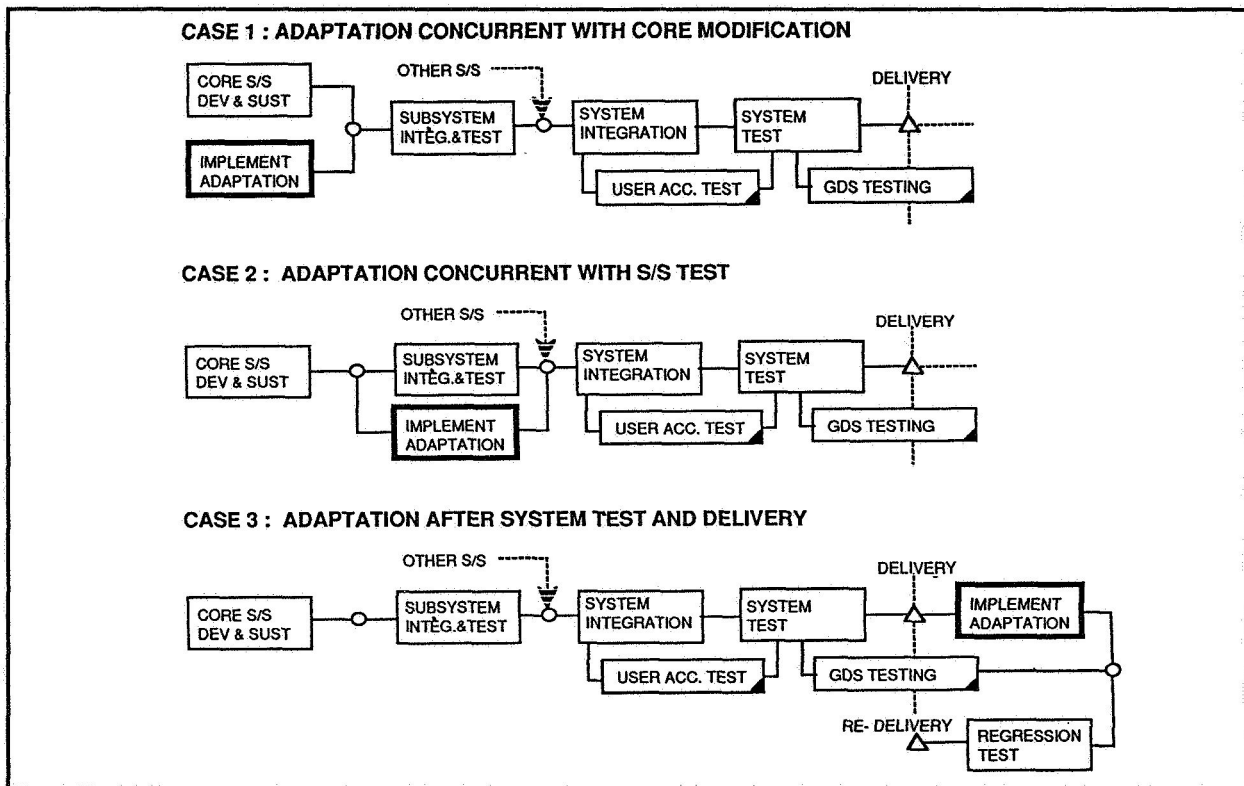


Figure 3. Three Basic Situations of Integration & Test of Multimission System Elements with Project Adaptations